ERDC/CRREL TN-15-1

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Engineering for Polar Operations, Logistics, and Research (EPOLAR)

Pegasus Airfield Repair and Protection

Laboratory Trials of White Ice Paint to Improve the Energy Reflectance Properties of the Glacial-Ice Runway Surface

Jason C. Weale

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Final Report

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United States Antarctic Program
Arlington, VA 22230

Under Engineering for Polar Operations, Logistics, and Research (EPOLAR)
EP-ANT-14-56, “White paint on Pegasus for reduced albedo”

Abstract

The U.S. Antarctic Program at the National Science Foundation (NSF) Division of Polar (PLR) is currently in the planning stages of a logistics support project to reestablish an all-season wheeled airfield to service McMurdo Station. In the interim, NSF-PLR is also investigating remedial and triage-type remedies to keep the existing Pegasus White Ice Runway viable for as long as possible with hopes of reducing the annual closure period at the height of summer warmth. This project conducted laboratory-scale concept tests of applying white ice paint, as used in skating arenas, to improve glacial-ice solar-energy reflectance properties in areas previously compromised by melt and refreeze.

We prepared samples for expedient spectroradiometer tests at our laboratory. The results of our tests indicate that there is no difference in reflectance response between 3 in. and 5 in. of snow cover over glacial ice whether the ice surface is painted or not. However, our results also indicate that the white paint on bare ice performs extremely well over the entire spectrum of visible through medium-infrared incoming energy, averaging almost 90% reflectance. The bare fresh ice peaked at only 50% reflectance in the visible spectrum and rapidly dropped-off to almost 0% in the near and medium-infrared spectra.

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Preface

This study was conducted for the National Science Foundation (NSF), Division of Polar Programs (PLR), United States Antarctic Program (USAP), under EP-ANT-14-56, "White paint on Pegasus for reduced albedo." The technical monitor was George Blaisdell, Chief Program Manager, NSF-PLR, USAP.

The work was performed by Jason C. Weale (Force Projection and Sustainment Branch, Dr. Edel Cortez, Chief), U.S. Army Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory (ERDC-CRREL). At the time of publication, Dr. Lindamae Peck was Acting Chief of the Research and Engineering Division, and Kevin Knut was Technical Director for Earth Sciences and Engineering. The Deputy Director of ERDC-CRREL was Dr. Lance Hansen, and the Director was Dr. Robert Davis.

The author thanks Dr. Don Perovich for his assistance in collecting and interpreting the spectroradiograph data and also thanks Dr. Zoe Courville and Lauren Farnsworth for their assistance preparing the samples.

COL Jeffrey R. Eckstein was Commander of ERDC, and Dr. Jeffery P. Holland was the Director.

Unit Conversion Factors

Multiply	By	To Obtain
degrees (angle)	0.01745329	radians
feet	0.3048	meters
gallons (U.S. liquid)	3.785412 E-03	cubic meters
inches	0.0254	meters
pounds (mass)	0.45359237	kilograms

1 Introduction

The Pegasus White Ice Runway at McMurdo Station, Antarctica, has experienced significant melting during the past two austral summers (2012–2013 and 2013–2014). Large melt areas on the runway surface caused the U.S. Antarctic Program (USAP) to close the airfield for a period of weeks; and in the case of the most recent summer (2013–2014), the runway was closed in December 2013 and was not reopened to wheeled aircraft. The runway closure for wheeled aircraft created a logistical challenge as all programmed C-17 flights were subsequently cancelled, and the station-closure airlift burden was shifted to the smaller and more valuable (for deep field airlift) LC-130 fleet.

The USAP at the National Science Foundation (NSF) Division of Polar (PLR) is currently in the planning stages of a logistics support project to re-establish an all-season wheeled airfield to service McMurdo Station. In the interim, NSF-PLR is also investigating remedial and triage-type remedies to keep the existing Pegasus White Ice Runway viable for as long as possible with hopes of reducing the annual closure period at the height of summer warmth. Therefore, this project is investigating the concept of applying white ice paint, as used in skating arenas, to improve glacial-ice solar-energy reflectance properties in areas previously compromised by melt and refreeze. The hope is that application of the paint will increase reflectance, reduce the propensity for these locations to melt in subsequent years, and thus provide a measure of protection for the lower-albedo damage areas.

2 White Ice Paint

A number of vendors supply a variety of powdered and pre-mixed paint products to the ice rink industry. Although the white color of rinks is best known for its visual enhancement of sporting events (hockey, figure skating, curling, etc.), the original purpose for painting rinks white was to help reduce ice softening caused by high-energy light fixtures shining directly down on ice surfaces. With the advent and integration of high-lumen, low-energy stadium lighting, a wide variety of paint colors are now used to decorate ice surfaces as the potential for ice softening by lighting is minimal.

The U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) obtained two 22 lb bags of a paint-powder product called “Base Coat White” manufactured by White Ice LTD of Calgary, CA, and distributed through U.S. Arena Supply in Exeter, NH (Figure 1). We chose the powder-based product over a liquid-based product because it is the most economical alternative for shipment to McMurdo should NSF-PLR recommend field trials. Though outside the scope of this small-scale study, water-based, pre-mixed paints with reportedly brighter and whiter properties are available and can be obtained and tested to compare against the powder-based paint.

Figure 1. “Base Coat White” paint manufactured by White Ice LTD of Calgary, CA, and supplied by U.S. Arena Supply in Exeter, NH.

3 Test Preparation

3.1 Sample preparation

We prepared six samples for expedient tests. The control series of samples consisted of 3 in. thick, bare, fresh ice; 3 in. thick, bare, fresh ice covered with about 3 in. of compacted snow; and 3 in. thick, bare, fresh ice covered with about 5 in. of compacted snow. The painted series of samples consisted of identical sections with the addition of White Ice paint applied to the surface of the bare fresh ice in all cases. We prepared all of the samples in 2 ft × 3 ft × 8 in. deep plastic tubs for ease of transport between our cold rooms and the outdoors for reflectance measurements (Figure 2).

Figure 2. 3 in. thick, bare, fresh ice (*left*); and 3 in. thick, bare ice covered with 3 in. of compacted snow (*right*).

We chose black tubs so that they would absorb as much incoming energy as possible and thus have the least influence on outgoing (reflectance) values measured for each sample section. The two compacted snow depths represented incremental values above and below 4 in., which is generally accepted as the maximum penetration depth of solar incident energy in clean snow. Our object here was to establish whether or not the paint applied to the ice surface would have a significant impact on the reflectance of snow-covered ice less than 4 in. below the snow surface.

3.2 Paint mixture and application

The White Ice paint instructions specified a mix ratio of one bag (22 lb) per 3.3 gal. of water. The powder was easy to mix in a small batch (5 gal. bucket) with a standard paint mixer attached to a cordless drill (Figure 3). Paint solids appeared to remain suspended throughout the short application process without the need to remix. Spraying is the manufacturer's

recommended application method for large projects (rink size and above). Our project necessitated the use of a roller, and this method proved adequate though it was important to be sure the roller was moving as it met the ice surface or the water-based paint immediately froze the roller cover to the ice. The paint is intended to freeze to the ice rather than to "dry" on a surface as most normal paints do.

Figure 3. White Ice paint mix instructions (*left*) and mix process (*right*).

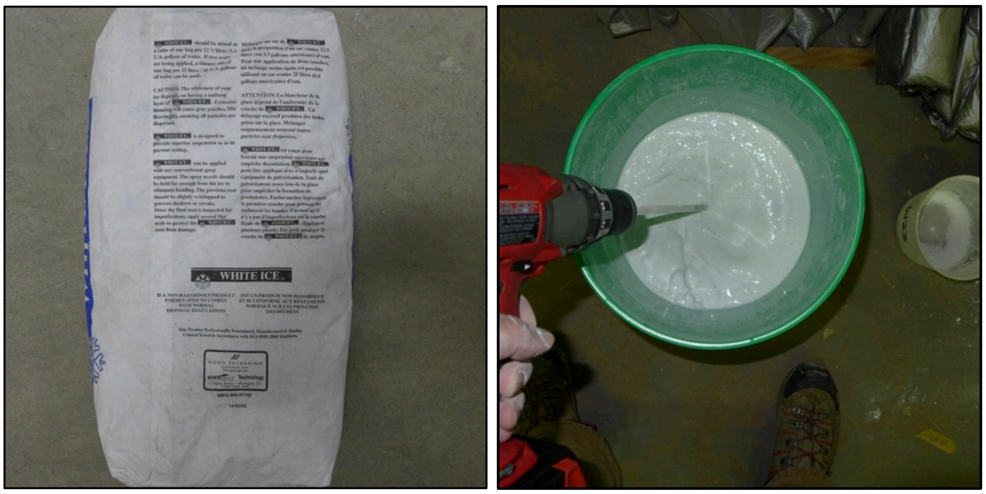


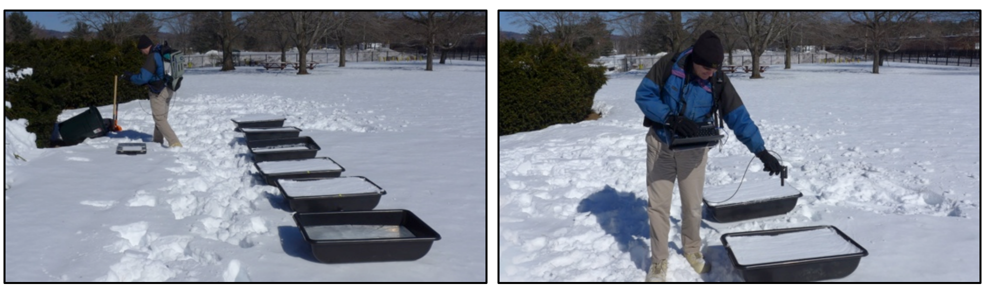
Figure 4 illustrates the application process of the White Ice paint and clearly shows the difference between the bare ice surface and the painted ice surface. Even with the "white" bubbles in the bare ice (as is typical in glacial ice), the paint provides a much more uniform surface

Figure 4. Application of White Ice paint to bare, fresh ice (*left*); and the ice surface following completion of rolling on the paint (*right*).

4 Findings

We conducted reflectance measurements to record the amount of broad-spectrum energy reflected by each of the test specimens. These tests were performed in bright sunshine in Hanover, NH, USA, on 28 February 2014. We used a FieldSpec 3 High-Res portable spectroradiometer, manufactured by ASD Inc., with a 5-degree cone receiver to collect the reflectance data. The device is capable of recording incident and outgoing solar radiation across the 350–2500 nm wavelength spectrum. A 5-degree cone receiver was required to ensure that we collected measurements from only the samples in the relatively small tubs. The measured reflectance was normalized to a Spectralon white plate (albedo of about 1.0). Figure 5 illustrates the data collection process.

Figure 5. Collecting reference measurements from Spectralon white plate for normalization (*left*) and broad-spectrum reflectance from samples (*right*). Note that the 5-degree sampling cone was held at approximately 24 in.

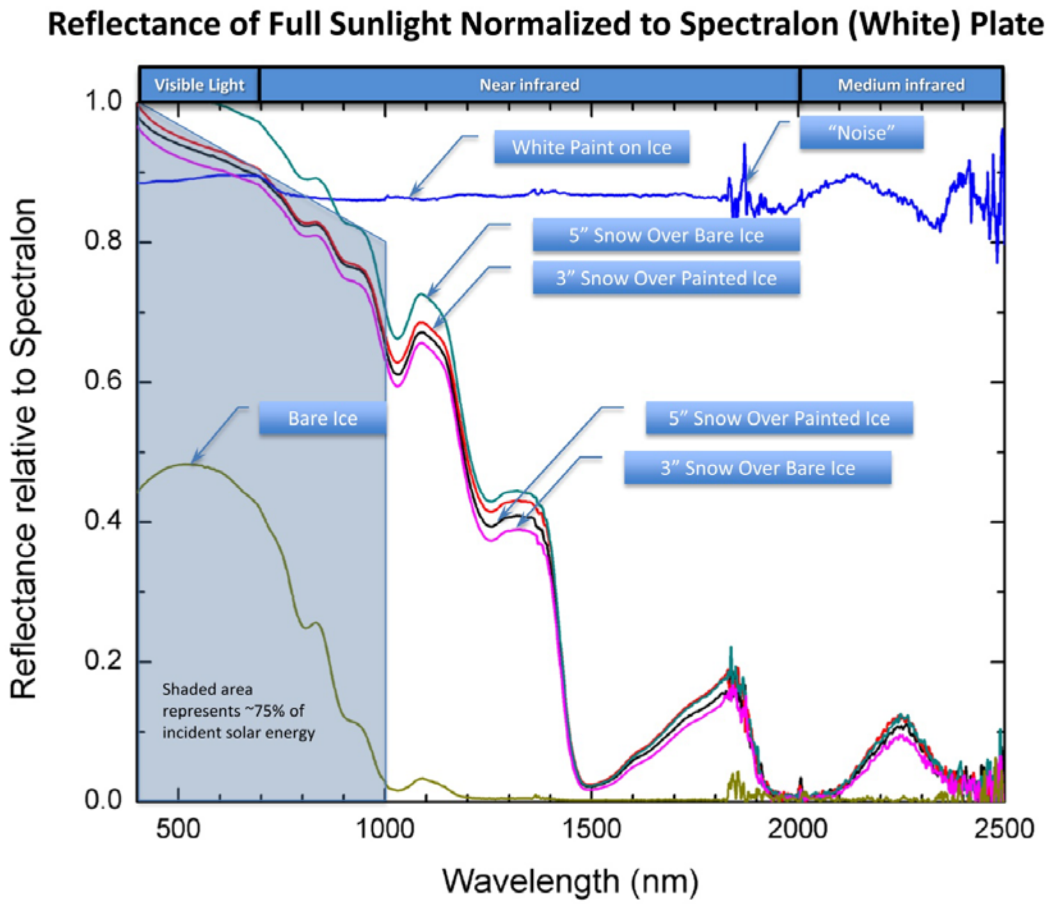


Though it is possible to correct the plots to McMurdo radiation levels and to convert the results to albedos, that effort would likely result in minimal changes to the relative magnitude of improvement associated with the application of white ice paint and are unlikely to impact the findings of this narrow-scope concept study. This study is focused on the relative differences in reflectivity for the varying painted ice and compacted snow treatments.

Albedo studies have shown that fresh, clean snow efficiently reflects the sun's rays. The four samples with compacted snow cover over the ice all reflected visible spectrum light as well or better than the white paint. Recall there were two samples each with 3 in. of compacted snow and two each with 5 in. of compacted snow where the ice was painted on one set prior to adding the snow cover. The results indicated that there was no

difference in reflectance response between the 3 in. and 5 in. of snow cover whether the ice surface was painted or not. This is illustrated by the closely clustered reflectance lines of these four samples (Figure 6). For the purposes of this study, we conclude that a clean, compacted snow cover of at least 3 in. will adequately reflect the vast majority of sun energy in the visible spectrum (about 400–900 nm).

Figure 6. Plot of spectroradiograph test results illustrating broad-spectrum sun energy reflectance values from 400–2500 nm wavelengths.



However, the plot also indicates that the white paint on bare ice performs extremely well over the entire spectrum of visible through medium-infrared incoming energy (about 350–2500 nm), averaging almost 90% reflectance whereas the bare fresh ice peaked at only 50% reflectance in the visible spectrum and rapidly dropped-off to almost 0% in the near and medium-infrared spectra.

The plot illustrates that about 75% of the incoming solar energy is delivered from about 350–1000 nm and the remaining 25% from about 1000–

2500 nm. Thus, for both bare fresh ice and snow-covered ice, there is very little energy reflected in the 1000–2500 nm spectrum. That fact raises the question as to whether or not paint sprayed on the compacted snow surface may improve reflectance over the entire spectra. It may yield results similar to those achieved by painting the bare ice and thus act as an expedient multi-spectral reflector during times of maximum incoming solar radiation.

5 Conclusions and Recommendations

Multiple issues need to be addressed before this product could be confirmed for widespread field applications. Though the paint is considered "environmentally safe" (ice arenas routinely send it down the drain with gray water), we need to observe its behavior in snow and ice to be sure that there are no detrimental longer-term impacts. One possible negative impact is that the paint could form an impenetrable vapor barrier, trap moisture migrating upward, and thus trigger the formation of a weak layer of hoar frost. An unknown is the impact of a melted ice and paint mixture and to what degree it could change both the albedo and strength characteristics of the white ice pavement once it re-freezes. On the positive side, there may be a benefit to mixing the dry paint powder with the water and ice slurry during remediation of melt pools to help increase the albedo during and after freezing. Another potential positive is that as temperatures rise, the albedo of snow drops; so it is likely the performance of the white ice paint in comparison to melted or metamorphosed snow may be much better than that of clean, cold, fine-grained snow.

With the acknowledgment of the potential challenges discussed above, we recommend further tests to observe whether or not white paint applied directly to ice runway surfaces is a viable solution to have in our toolkit to reduce both downtime and the loss of strength and integrity in snow and ice infrastructure. The results presented here indicate it is worthwhile to take action and to initiate larger-scale field studies—perhaps in McMurdo.

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14. ABSTRACT
The U.S. Antarctic Program at the National Science Foundation (NSF) Division of Polar (PLR) is currently in the planning stages of a logistics support project to reestablish an all-season wheeled airfield to service McMurdo Station. In the interim, NSF-PLR is also investigating remedial and triage-type remedies to keep the existing Pegasus White Ice Runway viable for as long as possible with hopes of reducing the annual closure period at the height of summer warmth. This project conducted laboratory-scale concept tests of applying white ice paint, as used in skating arenas, to improve glacial-ice solar-energy reflectance properties in areas previously compromised by melt and refreeze.

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